

Physics	Group-I	PAPER: II
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Prove that Coulomb's law obeys third law of motion.

Ans Consider two like charges q_1 and q_2 having a distance r between them. If we denote the force exerted on q_2 by q_1 as \vec{F}_{21} and that on charges q_1 due to q_2 as \vec{F}_{12} .

If \hat{r}_{21} is a unit vector directed from q_1 to q_2 and \hat{r}_{12} is the unit vector directed from q_2 to q_1 then

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{21} \quad (i)$$

$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

$$\hat{r}_{21} = -\hat{r}_{12}$$

Putting this in equation (i)

$$\therefore \vec{F}_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} (-\hat{r}_{21})$$

$$\vec{F}_{21} = - \left(\frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r^2} \hat{r}_{12} \right)$$

$$\therefore \vec{F}_{21} = -\vec{F}_{12}$$

Hence Coulombs force is mutual force, it means that if q_1 exerts a force on q_2 then q_2 also exerts an equal and opposite force on q_1 . Coulombs force is also known as electrostatic force and force of interaction.

(ii) Define potential gradient and give its SI units.

Ans The quantity $\frac{\Delta V}{\Delta r}$ gives the maximum value of the rate of change of potential with distance because the charge

has been moved along a field line along which the distance Δr between the two plates is minimum. It is known as potential gradient. Thus the electric intensity is equal to the negative of the gradient of potential. The negative sign indicates that the direction of E is along the decreasing potential.

The unit of electric intensity is volt/metre which is equal to NC^{-1} as shown below:

$$1 \frac{\text{volt}}{\text{metre}} = 1 \frac{\text{joule/coulomb}}{\text{metre}} = 1 \frac{\text{newton} \times \text{metre}}{\text{metre} \times \text{coulomb}} = 1 \frac{\text{newton}}{\text{coulomb}}$$

(iii) Suppose that you follow an electric field line due to a positive point charge. Do electric field and the potential increase or decrease? Explain.

Ans If we follow an electric field line due to a positive point charge, then it means that we are moving away from point charge. Thus, the distance from the charge increases. Due to increase of distance from positive charge, both electric intensity and voltage will decrease as it is clear from the following relations:

$$E \propto \frac{1}{r^2}$$

and

$$V \propto \frac{1}{r}$$

(iv) Define electric polarization and electric dipole.

Ans **Electric polarization:**

The phenomenon of re-distribution of charges in the dielectric substance under the influence of external electric field is called electric polarization.

Electric Dipole:

An electric dipole is a separation of positive and negative charges. The simplest example of this is a pair of electric charges of equal magnitude but opposite signs, separated by some distance.

(v) Define electromagnetism and give the name of one device in which electromagnetism is used.

Ans It is the branch of Physics which deals with the study of magnetic field associated with the moving charges or current. In galvanometer, electromagnetism is used.

(vi) State Ampere's law and write it in mathematical form.

Ans Ampere's law states that the sum of the quantities $B \cdot \Delta L$ for all path elements into which the complete loop has been divided equals μ_0 times the total current enclosed by the loop.

Mathematically,

$$\sum_{r=1}^n (B \cdot \Delta L)_r = \mu_0 I$$

(vii) What is Lorentz force? Write its mathematical expression.

Ans Lorentz force:

When a charge particle q is moving with velocity \vec{v} in a region where there is an electric field \vec{E} and magnetic field \vec{B} , the total force \vec{F} is the vector sum of the electric force $q\vec{E}$ and magnetic force $q(\vec{v} \times \vec{B})$, that is,

$$\begin{aligned}\vec{F} &= \vec{F}_e + \vec{F}_B \\ \vec{F} &= q\vec{E} + q(\vec{v} \times \vec{B}).\end{aligned}$$

This force \vec{F} is known as the Lorentz force.

(viii) What is CRO? Write the name of any four main parts of it.

Ans Cathode Ray Oscilloscope (CRO) is a very versatile electronic instrument which is, in fact, a high speed graph plotting device.

Name of four main parts of CRO is given below:

1. Electron Gun
2. Deflecting Plates
3. Sinusoidal Voltage
4. Synchronization control

(ix) Give the two techniques to improve the efficiency of a transformer.

Ans To improve the efficiency, care should be exercised, to minimize all the power losses. For example, core should be assembled from the laminated sheets of a material whose hysteresis loop area is very small. The insulation between lamination sheets should be perfect so as to stop

the flow of eddy currents. The resistance of primary and secondary coils should be kept to a minimum.

(x) Define self-induction and self-inductance.

Ans Self Induction:

The phenomenon in which a changing current in a coil induces an emf in itself is called self induction.

Self Inductance:

The ratio of the emf induced in the coil to the time rate of change of current in the same coil is called self inductance.

(xi) State Faraday's law and write it in mathematical form.

Ans It states that the induced emf is numerically proportional to the rate of change of flux.

Mathematically,

$$\epsilon_s = -N_s \frac{\Delta\phi_s}{\Delta t}$$

(xii) Show that emf (ϵ) and $\frac{\Delta\phi}{\Delta t}$ have the same units.

Ans As we know that

$$\epsilon = \frac{W}{q} = \frac{\text{Unit of work}}{\text{Unit of charge}} = \frac{J}{C}$$

$$\therefore \text{unit of } \epsilon = J/C = \text{volt}$$

Hence unit of $\epsilon = \text{volt}$

(1)

$$\begin{aligned} \text{Unit of } \frac{\Delta\phi}{\Delta t} &= \frac{B \cdot \Delta A}{\Delta t} = \frac{N A^{-1} m^{-1} m^2}{s} \\ &= \frac{N A^{-1} m}{s} = \frac{N \times m}{A \times s} \end{aligned}$$

But $N \times m = \text{Joule} = J$

$A \times s = \text{coulomb} = C$

$$\therefore \text{unit of } \frac{\Delta\phi}{\Delta t} = \frac{J}{C} = \text{volt}$$

$$\therefore \boxed{\text{unit of } \frac{\Delta\phi}{\Delta t} = \text{volt}}$$

(2)

Hence, it clear from eqs. (1) and (2), both ε and $\Delta\phi/\Delta t$ have the same units.

3. Write short answers to any EIGHT (8) questions: (16)

- (i) Define temperature coefficient of resistance and write its formula.

Ans "The fractional change in resistance per kelvin is known as the temperature coefficient of resistance."

Unit:

The SI unit of α (temperature coefficient) is K^{-1} .

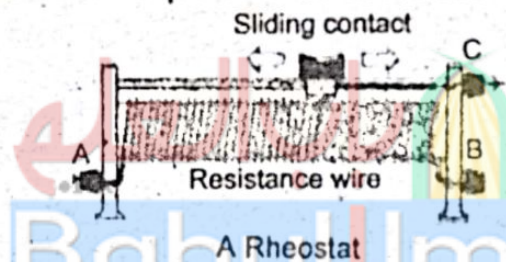
The formula of temperature coefficient of resistance is:

$$\alpha = \frac{R_t - R_0}{R_0 \Delta t}$$

- (ii) Write two uses of rheostat and draw their diagrams.

Ans The uses of rheostat are as follows:

1. A Rheostat is used as a variable resistance.
2. It is also used as potential divider.



- (iii) Two charged particles are projected into a region where there is a magnetic field perpendicular to their velocities. If the charges are deflected in opposite directions, what can you say about them?

Ans The charged particles that are projected across the magnetic field perpendicular to their velocities, are:

$$\vec{F}_m = q (\vec{V} \times \vec{B})$$

This magnetic force on charged particles tends to deflect the particle into a curved path. If the charged particles are deflected opposite to each other, then the particles are oppositely charged, i.e., one particle may be positively charged and the other one may be negatively charged.

(iv) Define choke and write its advantage in A.C. circuits.

Ans Choke:

An inductor used in a circuit to gain a high impedance to frequencies above a specified frequency range without appreciably limiting the flow of direct current is known as choke or choke coil.

Advantage:

It is used in A.C. circuit to limit current with extremely small wastage of energy as compared to a resistance or a rheostat.

(v) What is the main advantage of three phase A.C. supply?

Ans The main advantage of three phase supply is that total load of the house or factory is divided into three parts. In this way, none of the line is overloaded. If a heavy load consisting of a number of air-conditioners and motor etc. is supplied power from a single phase supply, then voltage of single phase source will drop.

(vi) A sinusoidal current has rms value of 15A. What is the maximum value?

Ans Root mean square value of A.C. is given by,

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$\Rightarrow I_0 = \sqrt{2} I_{rms}$$

$$I_0 = 1.414 \times 15$$

$$I_0 = 21.21 \text{ A}$$

(vii) Define crystal lattice and give one example.

Ans A crystalline solid consists of three dimensional pattern that repeats itself over and over again. This smallest three dimensional basic structure is called unit cell. The whole structure obtained by the repetition of unit cell is known as crystal lattice.

Example:

The example of crystal lattice is the pattern of NaCl (Table salt).

(viii) Define modulus of elasticity and write its formula.

Ans Modulus of elasticity:

The ratio of stress to strain is called modulus of elasticity. Mathematically, it can be written as

$$\text{Modulus of elasticity} = \frac{\text{stress}}{\text{strain}}$$

(ix) What is meant by strain energy?

Ans Strain energy:

"The potential energy stored in a body by virtue of an elastic deformation, equal to the work that must be done to produce this deformation is known as strain energy."

(x) Define open loop gain of an operational amplifier and write its formula.

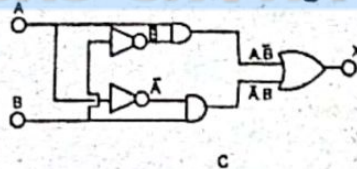
Ans The ratio of output voltage V_o to the voltage difference between non-inverting and inverting inputs where there is no external connection between the output and the inputs is called open loop gain of an operational amplifier. It is denoted by A_{OL} .

$$A_{OL} = \frac{V_o}{V_+ - V_-} = \frac{V_o}{V_i}$$

(xi) Draw diagram of exclusive OR gate and write its formula.

Ans Diagram:

The diagram of exclusive OR gate is given below:



Formula:

The formula of exclusive OR gate is:

$$X = AB + \bar{A}\bar{B}$$

(xii) Why ordinary silicon diodes do not emit light?

Ans Ordinary silicon diode does not emit light because of opaque nature of silicon. Wavelength of photon emitted by silicon diode is greater than wavelength of visible light (lies in infrared region) which is not visible.

4. Write short answers to any SIX (6) questions: (12)

(i) Is it possible for an object to move with speed of light? Justify your answer.

Ans In special theory of relativity, it is impossible to accelerate an object to the speed of light, or for a massive object to move at the speed of light.

- (ii) What are black body radiations and how can you get a black body?

Ans Black body radiations:

A body which absorbs all the radiations falling upon it is called a black body and when heated, it emits radiations which are known as black body radiations.

Black body can be made by making a small hole in the wall of rough cavity whose inner shell walls are coated with soot or lamp black.

- (iii) Which photon, red, green or blue carries the most:
(a) Energy, and (b) Momentum?

Ans (a) Energy:

According to the relation $E = hf$, the photons of blue light having larger frequency must have the largest value of energy as compared with photons of red and green colour light.

(b) Momentum

Since $p = \frac{h}{\lambda}$ (Momentum is inversely proportional to wavelength)

and $\lambda = \frac{1}{f}$ (Wavelength is inversely proportional to frequency)

These relations show that if frequency is small, λ is large and hence, 'p' is small. This proves that red light photons have smaller value of momentum than blue light.

- (iv) Find the speed of the electron in the first Bohr orbit.

Ans Data:

For First Bohr orbit:

$$n = 1$$

To find:

Speed of electron,
 $v = ?$

Calculation:

Using the relation,

$$v_n = \frac{2\pi ke^2}{nh}$$

$$v_1 = \frac{2 \times 3.14 \times 9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.63 \times 10^{-34}}$$

$$v_1 = 2.18 \times 10^6 \text{ ms}^{-1}$$

Hence,
Speed of electron:

$$v_1 = 2.18 \times 10^6 \text{ ms}^{-1}$$

(v) How can the spectrum of hydrogen contain so many lines, when hydrogen contains one electron?

Ans When the energy is supplied to the atom of hydrogen, it will be excited. Then, its single electron will jump from its ground state to some higher energy level. Now, when, it de-excites from higher level to ground level by several jumps, spectral lines of different wavelengths are emitted. That is why the spectrum of hydrogen contains many lines.

(vi) In ${}_{92}^{235}\text{U}$, find:

- (a) Atomic number (b) Charge number
(c) Number of neutrons (d) Number of electrons

Ans (a) Atomic number:

In ${}_{92}^{235}\text{U}$, 92 is atomic number.

(b) Charge number:

$$Z = 92$$

(c) Number of neutrons:

$$N = A - Z$$

$$= 235 - 92$$

$$N = 143$$

(d) Number of electrons:

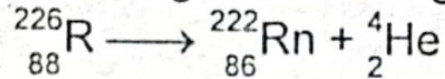
$$Z = 92$$

(vii) What is radioactive decay? Give an example.

Ans Whenever a radioactive element emits α or β -particles, this element changes into a new element. This phenomenon is called radioactive decay.

Example:

Radium changes to radon gas.



(viii) What information is revealed by the length and shape of the tracks of an incident particle in Wilson cloud chamber?

Ans In Wilson cloud chamber, the length and shape of the tracks give information about the penetrating power and ionization energy.

For Example:

1. α -particles produce thick and continuous tracks due to their high ionization power and greater mass.
2. β -particles produce thinner, short and discontinuous tracks due to their smaller mass and smaller ionizing power.

(ix) How can radioactivity help in the treatment of cancer?

Ans Radiotherapy with γ rays from cobalt-60 is often used in treatment of cancer. The γ rays are carefully focussed on the malignant tissue.

SECTION-II

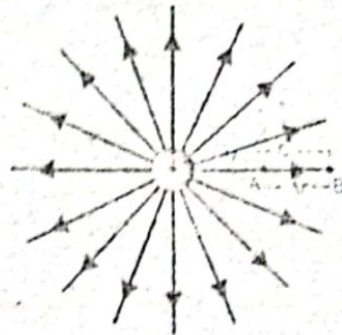
NOTE: Attempt any THREE (3) questions.

Q.5.(a) Derive an expression for the potential at a certain point in the field of a positive point charge. (5)

Ans **Electric Potential at a Point Due to a Point Charge:**

In this case, we have to derive an expression for the potential at a certain point in the field of a positive point charge 'q'. This can be done by bringing a unit positive charge from infinity to that point keeping the charge in equilibrium. For this purpose, we use the equation in the form $\Delta V = -E\Delta r$, provided electric intensity E remains

constant. However, in this case, E varies inversely as square of distance from the point charge, it no more remains constant, so, we use basic principle to find the electric potential at a point. The field is radial as shown in the figure.



Consider two points A and B, infinitesimally close to each other, so that E remains almost constant between the points. The distance of points A and B from 'q' are ' r_A ' and ' r_B ' respectively and distance of midpoint of space interval between points A and B is ' r ' from charge 'q'.

From figure, we know that

$$r_B = r_A + \Delta r \quad (1)$$

$$\text{or } \Delta r = r_B - r_A \quad (2)$$

As ' r ' represents midpoint of interval between A and B, so

$$r = \frac{r_A + r_B}{2} \quad (3)$$

The magnitude of electric intensity at this point is

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \quad (4)$$

As the points A and B are very close then, as a first approximation, we can take the arithmetic mean to be equal to geometric mean which gives

$$\frac{r}{r_A} = \frac{r_B}{r}$$

Therefore, $r^2 = r_A r_B$

Substituting this value of r^2 in eq. (4), we have

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r_A r_B} \quad (5)$$

Now, if a unit positive charge is moved from point B to A, the work done is equal to the potential difference between point A and B,

$$V_A - V_B = -E (r_A - r_B)$$

$$\text{or } V_A - V_B = E (r_B - r_A) \quad (6)$$

Substituting the value of E from eq. (5), we have

$$V_A - V_B = \frac{q}{4\pi\epsilon_0} \left(\frac{r_B - r_A}{r_A r_B} \right)$$

$$\text{or } V_A - V_B = \frac{q}{4\pi\epsilon_0} \left(\frac{1}{r_A} - \frac{1}{r_B} \right) \quad (7)$$

To calculate absolute potential or potential at point A, point B is assumed to be at infinity, therefore, $V_B = 0$ and hence,

$$r_B = \frac{1}{r_\infty} = \frac{1}{\infty} = 0$$

So, Eq. (7) becomes

$$V_A = \frac{1}{4\pi\epsilon_0} \frac{q}{r_A} \quad (8)$$

The above equation gives the potential at any point that is at a distance 'r' from a point charge 'q'. If we drop the subscript 'A' from this equation, then the general expression for electric potential ' V_r ' at a distance 'r' from the charge 'q' is given by

$$V_r = \frac{1}{4\pi\epsilon_0} \frac{q}{r} \quad (9)$$

- (b) The resistance of an iron wire at 0°C is $1 \times 10^4 \Omega$. What is the resistance at 500°C if the temperature co-efficient of resistance of iron is $5.2 \times 10^{-3} \text{ K}^{-1}$? (3)

Ans Given:

Resistance at $0^\circ\text{C} = R_0 = 1 \times 10^4 \Omega$

Initial temperature = $t_1 = 0^\circ\text{C} = 273 \text{ K}$

$$\text{Final temperature} = t_2 = 500^\circ\text{C} = 500 + 273 = 773 \text{ K}$$

$$\text{Temperature coefficient of resistance} = \alpha = 5.2 \times 10^{-3} \text{ K}^{-1}$$

$$\begin{aligned}\text{Rise in temperature} &= \Delta t = t_2 - t_1 \\ &= 773 - 273 \\ &= 500 \text{ K}\end{aligned}$$

$$\text{Resistance at } 500^\circ\text{C} = R_t = ?$$

Using the formula,

$$R_t = R_0 (1 + \alpha \Delta t)$$

Putting values,

$$\begin{aligned}R_t &= 1 \times 10^4 (1 + 5.2 \times 10^{-3} \times 500) \\ &= 1 \times 10^4 \times 3.6\end{aligned}$$

$$R_t = 3.6 \times 10^4 \Omega$$

Q.6.(a) What is transformer? Describe its principle, construction and working. (5)

Ans **Transformer:**

A transformer is an electrical device to change a given alternating emf into larger or smaller alternating emf. It can step-up and step-down the given alternating emf.

Principle:

The transformer works on the principle of mutual induction between two coils. i.e., "A changing current in one coil induces an emf in another nearby coil."

Construction:

A transformer consists of two sets of copper coils wound on the same iron core. The coil to which A.C power is supplied is called primary coil and that from which power is delivered to the circuit is called the secondary coil.

Working:

When the alternating emf V_p is applied to the primary coil, the changing flux is produced in it. Let, at some instant 't', the flux in the primary coil is changing at the rate of $\frac{\Delta\phi}{\Delta t}$, then the emf induced in the primary coil is given by

$$\text{Self-induced emf} = \varepsilon_p = -N_p \frac{\Delta\phi}{\Delta t}$$

where N_p is the number of turns in the primary coil.

If the resistance of the primary coil is negligible, then, the back emf is equal and opposite to the applied voltage, i.e.,

$$V_p = -\varepsilon_p$$

$$V_p = N_p \frac{\Delta\phi}{\Delta t} \quad (1)$$

Since, the primary and secondary coils are magnetically linked, so the rate of change of flux in the secondary coil will also be $\frac{\Delta\phi}{\Delta t}$. Thus, the magnitude of induced emf across the secondary coil will be

$$V_s = N_s \frac{\Delta\phi}{\Delta t} \quad (2)$$

where N_s is the number of turns in the secondary coil.

Dividing eq. (2) by eq. (1), we get

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

This is the transformer equation, which defines the function of transformer.

(b) A power line 10.0 m high carries a current 200 A. Find the magnetic field of the wire at the ground. (3)

Ans Given:

Height = distance from ground = $r = 10$ m

Current = $I = 200$ A

$$\mu_0 = 4\pi \times 10^{-7} \text{ Wb A}^{-1}\text{m}^{-1}$$

Magnetic field = $B = ?$

Using formula,

$$B = \frac{\mu_0 I}{2\pi r}$$

Putting values,

$$B = \frac{4\pi \times 10^{-7} \times 200}{2\pi \times 10}$$

$$\Rightarrow \boxed{B = 4.0 \times 10^{-6} \text{ T}}$$

$$\text{Magnetic field} = B = 4.0 \times 10^{-6} \text{ T}$$

Q.7.(a) Define modulation, electromagnetic waves. And in a R-L series circuit, will the current lag or lead the voltage? Illustrate your answer by a vector diagram. (5)

Ans Modulation:

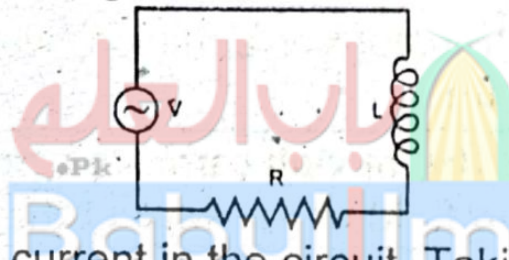
Modulation is the process of combining low frequency signal with a high frequency radio waves called carrier waves. The resultant wave is called the modulated carrier wave.

Electromagnetic waves:

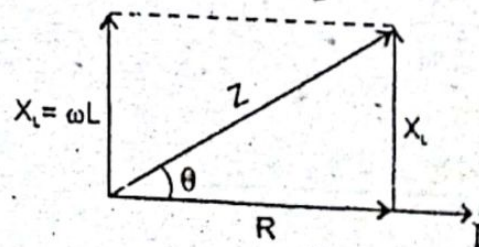
The wave which require no medium for transmission and which rapidly propagate through vacuum are called electromagnetic waves.

R-L Series Circuit:

Consider a series combination of resistance R and an inductor ' L ' connected with an alternating voltage source as shown in fig.



Let I_{rms} be current in the circuit. Taking the current as reference, so it is represented by a horizontal line. Since, the P.d across resistance $I_{\text{rms}} R$ is in phase with current, so the vector line of resistance R is drawn along the current line. As the potential difference across the inductor $V_L = I_{\text{rms}} X_L$ leads the current by 90° , so vector line of reactance X_L is drawn at right angle to R line.



The impedance Z of the circuit is obtained by the vector sum of R and $X_L = \omega L$ lines as

$$\vec{Z} = \vec{R} + \vec{X}_L$$

$$\Rightarrow Z = \sqrt{R^2 + (\omega L)^2}$$

Phase of R - L Circuit:

The angle which the Z -line makes with R -line gives the phase difference between the voltage and the current which is given by:

$$\theta = \tan^{-1} \left(\frac{X_L}{R} \right)$$

$$\theta = \tan^{-1} \left(\frac{\omega L}{R} \right)$$

$$= \tan^{-1} \left(\frac{2\pi f L}{R} \right)$$

In R-L circuit, the voltage leads the current by $\theta = \tan^{-1} \left(\frac{\omega L}{R} \right)$.

- (b) The current flowing into the base of a transistor is $100 \mu A$. Find the ratio $\frac{I_C}{I_E}$, if the value of current gain β is 100. (3)

Ans Given data:

$$\begin{aligned} \text{Current flowing through the base} &= I_B = 100 \mu A \\ &= 100 \times 10^{-6} A \end{aligned}$$

$$\text{Current gain} = \beta = 100$$

To determine:

- Current flowing through the collector = $I_C = ?$
- Current flowing through the emitter = $I_E = ?$

Calculations:

- (i) Collector current can be calculated by using the relation

$$I_C = \beta I_B$$

Substituting the values, we have

$$\begin{aligned} I_C &= 100 \times 100 \times 10^{-6} A \\ &= 10000 \times 10^{-6} A \end{aligned}$$

$$= 10 \times 10^{-3} \text{ A}$$

$$I_C = 10 \text{ mA}$$

(ii) We know that

$$I_E = I_C + I_B$$

$$\text{or } I_E = 10 \text{ mA} + 100 \times 10^{-6} \text{ A}$$

$$= 10 \text{ mA} + 100 \times 10^{-6} \times 10^3 \text{ mA}$$

$$(\because 1 \text{ A} = 10^3 \text{ mA})$$

$$= 10 \text{ mA} + 100 \times 10^{-3} \text{ mA}$$

$$I_E = 10.1 \text{ mA}$$

$$\frac{I_C}{I_E} = \frac{10 \text{ mA}}{10.11 \text{ mA}}$$

$$\frac{I_C}{I_E} = 0.99$$

Q.8.(a) Define stress and strain. What is strain energy? Calculate its value in terms of modulus of elasticity. (5)

Ans Stress:

The force applied on unit area to produce change in shape, volume or length of a body is called stress.

$$\text{Stress} = \frac{F}{A}$$

Strain:

The measure of the deformation of a solid when stress applied on it is called strain.

Strain energy:

The energy stored in a body by virtue of an elastic deformation equal to work done that must be done to produce this deformation is known as strain energy.

Consider, a wire suspended by attaching a weight at the other end. The stretching force (F) can be increased by adding more weight (W).

Suppose, the force F_1 produces the extension ' l_1 ' in the wire. In order to calculate the work done by the force

' F_1 ', the extension ' l_1 ' is divided into large number of small extensions each of length Δx . The extension Δx is so small that the force is assumed constant in Δx . The work done by the force F in producing the extension Δx is

$$\Delta W = F \times \Delta x$$

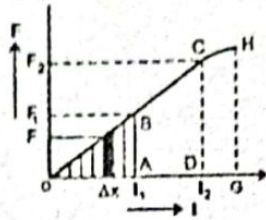


Fig. Energy in stretched wire.

This work done is represented by the area of the shaded strip in the fig. Similarly, the total work done in producing the extension l_1 is equal to the sum of area of all strips between 0 to A. This is equal to area of ΔOAB .

Thus,

$$\text{Work done} = \text{Area of } \Delta OAB \quad (\because OA = l_1, AB = F_1)$$

$$= \frac{1}{2} \times OA \times AB$$

$$W = \frac{1}{2} l_1 \times F_1 \quad (1)$$

This work done is stored in the wire in the form of strain energy.

In terms of Elastic Constant:

If 'A' is the area of cross-section of wire and L its total length, then the modulus of elasticity 'E' of the wire is given by

$$E = \frac{\text{Stress}}{\text{Strain}} = \frac{F_1/A}{l_1/L}$$

$$E = \frac{F_1}{A} \times \frac{L}{l_1}$$

$$\text{and } F_1 = \frac{EA \times l_1}{L}$$

Putting the value of F_1 in eq. (1), we get

$$\text{Work done} = \frac{1}{2} l_1 \times \frac{EA \times l_1}{L}$$

$$\text{or Strain Energy} = \frac{1}{2} \left[\frac{EA \times l_1^2}{L} \right] \quad (2)$$

This method is applicable for both the linear (elastic) and the non-linear (non-elastic) parts of the force-extension graph. If the extension occurs from O to G, the work done is equal to the area of OHG.

(b) What is the de-Broglie wavelength of an electron whose kinetic energy is 120 eV? (3)

Ans Given:

$$\text{K.E. of electron} = E = 120 \text{ eV}$$

$$= E = 120 \times 1.6 \times 10^{-19}$$

$$= E = 192 \times 10^{-19} \text{ J}$$

$$h = 6.625 \times 10^{-34} \text{ Js}$$

$$m = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{de-Broglie wavelength} = \lambda = ?$$

$$\lambda = \frac{h}{mv}$$

$$\text{K.E. } E = \frac{1}{2} mv^2$$

$$\Rightarrow mv = \sqrt{2mE}$$

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$$

Putting values,

$$\begin{aligned} \lambda &= \frac{6.625 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 192 \times 10^{-19}}} \\ &= \frac{6.625 \times 10^{-34}}{5.91 \times 10^{-24}} \end{aligned}$$

$$\boxed{\lambda = 1.12 \times 10^{-10} \text{ m}}$$

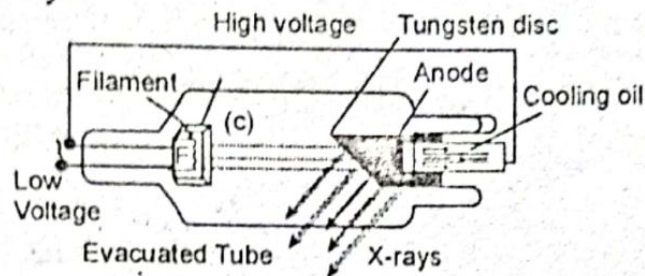
Q.9.(a) What is meant by inner shell transition and characteristic X-rays? How X-rays are produced? Write down any two properties and uses of X-rays. (5)

Ans The transition of inner shells electrons in heavy atoms gives rise to the emission of high energy photons or

X-rays. These X-rays consist of a series of specific wavelengths or frequencies and hence are called characteristics of X-rays.

Production of X-rays:

The following figure shows an arrangement of producing X-rays.



It consists of a high vacuum tube called X-ray tube. When the cathode is heated by the filament F, it emits electrons which are accelerated towards the anode T. If V is the potential difference between C and T, the kinetic energy K.E with which the electrons strike the target is given by

$$K.E = Ve$$

Suppose that these fast moving electrons of energy Ve strike a target made of tungsten or any other heavy element. It is possible that in collision, the electrons in the innermost shells such as K or L will be knocked out. Suppose that one of the electrons in the K shell is removed, thereby producing a vacancy or hole in that shell. The electron from the L shell jumps to occupy the hole in the K shell, thereby emitting a photon of energy $hf_{k\alpha}$ called the K_{α} X-ray given by

$$hf_{k\alpha} = E_L - E_K$$

It is also possible that the electron from the M shell might also jump to occupy the hole in the K shell. The photons emitted by K_{β} X-ray with energies.

$$hf_{k\beta} = E_M - E_K$$

These photons give rise to K_{β} X-ray and so on.

The photons emitted in such transitions i.e., inner shell transitions are called characteristic X-rays, because their energies depend upon the type of target material.

Uses of X-rays:

1. X-rays have many practical applications in medicine and industry.
2. X-rays can penetrate several centimeters into a solid matter.

3. The object to be visualized is placed between an X-ray source and a large sheet of photographic film.
4. A crack or air bubble allows greater amount on X-rays to pass. This appears as the dark area of the photographic film.
5. In flesh, light elements like carbon, hydrogen and oxygen predominate. These elements allow greater amount of incident X-rays to pass through them.

(b) A sheet of lead 5 mm thick reduces the intensity of a beam of γ -rays by a factor 0.4. Find half-value thickness of lead sheet which will reduce the intensity to half of its initial value. (3)

Ans Given:

Thickness of sheet = $x_1 = 5.0 \text{ mm} = 50 \times 10^{-3} \text{ m}$

Let, initial intensity = I_0

Reduce intensity = $I_1 = 0.4 I_0$

Second reduce intensity = $I_0 = 0.5 I_0$

Half-value thickness of sheet = $x_2 = ?$

Using the relation,

$$I = I_0 e^{-\mu x} \quad (1)$$

In first case, $I = 0.4 I_0$ and $x = x_1$

$$\therefore 0.4 I_0 = I_0 e^{-\mu x_1}$$

$$\Rightarrow e^{-\mu x_1} = 0.4$$

Taking log on both sides, we have

$$\ln e^{-\mu x_1} = \ln (0.4)$$

$$\Rightarrow -\mu x_1 \ln e = -0.916 \quad (\ln e = 1)$$

$$\mu x_1 = 0.916$$

Putting value of x_1 ,

$$\mu \times 5.0 \times 10^{-3} = 0.916$$

$$\mu = 183.2$$

To find half-value thickness x_2 of sheet,

Put $I = 0.5 I_0$ in eq. (1)

$$0.5 I_0 = I_0 e^{-\mu x_2}$$

$$\Rightarrow e^{-\mu x_2} = 0.5$$

Taking log on both sides, we get

$$\ln e^{-\mu x_2} = \ln(0.5)$$

$$-\mu x_2 \ln e = -0.693$$

Putting value of μ , we get

$$183.2 \times x_2 = 0.693$$

$$x_2 = \frac{0.693}{183.2} = 3.78 \times 10^{-3} \text{ m}$$

$$\Rightarrow \boxed{x_2 = 3.78 \text{ mm}}$$

